Comparison of the 1.5 Mile Run Times at 7,200 Feet and Simulated 850 Feet in a Hyperoxic Room.

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14. ABSTRACT
The 1.5 mile run test was developed in 1968 by Dr. Ken Cooper as an easy, inexpensive and relatively accurate way to estimate VO2 max in large groups of Air Force personnel. In January 2010, a new Air Force fitness test program was implemented, using the 1.5 mile run to test aerobic fitness, but there was no altitude adjustment for Air Force Bases located at moderate altitude. This study investigated if a significant difference in aerobic performance exists between moderate altitude (ALT) and sea level (SL) and, if it does exist, to what extent. This study was reviewed and approved by the USAFA IRB and all subjects signed an informed consent document (ICD). Fifty-five, fully informed, non-smoking male (38) and female (17) subjects participated in this study. Each subject completed a VO2 max test and then two 1.5 mile runs, one at 7,200 ft and one at simulated 850 ft (~26% O2). During the 1.5 mile runs, the subjects were able to see their distance and were in complete control of the treadmill speed so they could adjust their speed based on how they are feeling. The treadmill speed, elapsed time, and heart rate displays were covered so as not to influence the subjects? running speed. The subjects were blinded to the environmental condition they were running in. Results between conditions were analyzed using an ANOVA. The average max VO2?s for the subjects was 48.6 mL.kg-1.min-1 ranging from 35.2 to 64.8 mL.kg-1.min-1. A 30.6 seconds, or 4.2%, significant difference (p<.001) was observed between the two 1.5 mile runs. There were minimal differences between the runs for the first .75 miles. It was the second half of the test where the runs at ALT began to lag behind the SL runs. These differences were mainly due to a decreased hemoglobin oxygen saturation (p<.001).

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Executive Summary

Purpose:

The 1.5 mile run test was developed in 1968 by Dr. Ken Cooper as an easy, inexpensive, and relatively accurate way to estimate maximal oxygen update (VO_2 max), or aerobic fitness, in large groups of Air Force personnel. In 2004, an Air Force fitness program was implemented using the 1.5 mile test to estimate an airman's aerobic capacity. In 2005, an altitude adjustment was implemented for airmen stationed above 5,000 ft using an altitude adjustment formula recommended by the National Collegiate Athletic Association (NCAA). In January 2010, a new Air Force fitness test program was implemented, which continued to use the 1.5 mile run to test aerobic fitness, but the altitude adjustment for the Air Force Bases located at moderate altitude was removed. This study investigated if a significant difference in aerobic performance exists between moderate altitude and sea level and, if it does exist, to what extent.

Methods:

Fifty-five, fully informed, non-smoking male and female subjects participated in this study. The study was a simple within-subjects design. Each subject completed a VO_2 max test and then two 1.5 mile fitness tests, one at 7,200 ft and one at simulated 850 ft (~26% O2). During the 1.5 mile runs, the subjects were able to see their cumulative distance and were in complete control of the treadmill speed so they could adjust their speed based on how they were feeling. The treadmill speed, elapsed time, and heart rate displays were covered so as not to influence the subjects' running speed. The subjects were blinded to the environmental condition they were running in. Results between conditions were analyzed using an ANOVA.

Results and Conclusions:

The average maximal oxygen uptake (VO_2 max) for the subjects was 48.6 $mL \cdot kg^{-1} \cdot min^{-1}$, ranging from 35.2 to 64.8 $mL \cdot kg^{-1} \cdot min^{-1}$. A 30.6 seconds, or 4.4%, significant difference ($p<.001$) was observed between the two 1.5 mile fitness tests. These differences were mainly due to a decreased hemoglobin oxygen saturation ($p<.001$) during the second half of the 1.5 mile runs at moderate altitude. Our recommendation is that an altitude adjustment for the Air Force fitness test be reinstated for airmen testing at moderate altitude bases.

INTRODUCTION

Background and Objective:

A laboratory treadmill or bike maximal oxygen uptake (also known as VO_2 max) test is the single best measurement of cardio-respiratory health/fitness, as it is a measurement of how effective the body can deliver oxygen from the ambient environment to the exercising muscles. Thus, all the systems utilized for oxygen delivery and consumption (lungs, heart, circulatory system, and muscles) can be assessed. However, this test is very time consuming, labor intensive, and cost prohibited administering annually to every airman. The 1.5 mile run test was developed in 1968 by Dr. Ken Cooper as an easy, inexpensive, and relatively accurate way to estimate VO_2 max in large groups of Air Force personnel (Cooper, 1968). This 1.5 mile run test was used for over 15 years by the Air Force until it was replaced with the cycle ergometry test in 1992. In 2004, a new Air Force fitness program was released that once again implemented the 1.5 mile test to estimate an airman's aerobic capacity. In 2005, an altitude adjustment to the 1.5 mile test was implemented for airmen stationed above 5,000 ft using an altitude adjustment formula recommended by the National Collegiate Athletic Association (NCAA). This 1.75 point adjustment was awarded to all running scores to reflect physiological limitations in oxygen capacity while running at moderate elevations. In January 2010, another new Air Force fitness test program was implemented which still used the 1.5 mile run to estimate aerobic fitness, but the altitude adjustment for the Air Force Bases located at moderate altitude was removed. The following posts on the Air Force Personnel Center Fitness Program FAQ page are explanations on why this adjustment was removed:

> "The high altitude calculation was removed as all individuals are already given a temporary exemption of six weeks to adapt to the altitude differences between locations. After the first two weeks at a higher altitude, adaptations occur in the lungs, circulation, and muscles. This allows a member to perform aerobically at levels comparable to sea

> level. With six weeks to acclimatize and continue training at altitude, members' 1.5 mile run performance should not be appreciably degraded"

And

> "Exercise research indicates that a score adjustment for people taking the revised Air Force Physical Fitness Test at higher altitudes is not needed. The VO_2 max or aerobic fitness, the factor we are measuring with the 1.5 mile run, is not measurably altered in a non-acclimated member testing from sea level up to 7,000 feet. During the first two to three weeks of living and exercising at higher altitudes, people experience lung, circulation, and cellular improvements that allow them to perform aerobically at levels comparable to sea level.
>
> It should also be noted that the earliest an Air Force member would have to take the revised physical fitness test is six weeks after a Permanent Change of Station (PSC) to a higher altitude base. This gives members adequate time to acclimate themselves to the higher altitudes and continue their training.
>
> Members should also remain as fit as possible prior to a PCS so they can acclimate themselves easier to a higher altitude base. After arriving at a new base with higher altitudes, members should exercise at a lower intensity and progress to higher intensities at a gradual pace. They should also ensure they are hydrating at all times during any aerobic activity. Lastly, high altitudes do not have measurable performance effects on the muscle fitness or body composition test components of the revised physical fitness test." (Air Force Fitness Program)

As altitude is increased from sea level, barometric pressure decreases, and as a result there is less oxygen per given volume of air at moderate altitude (>5000 ft) than at sea level. This is known as hypobaric hypoxia. Although the body can partially adapt to this environment, primarily by increasing respiration rate and blood volume to partially compensate for the reduced availability of oxygen, several studies performed by personnel assigned to the USAFA Human Performance Lab have clearly demonstrated that the moderate altitude acclimatization process is lengthy (4 to 6+ months on average), and even with complete acclimatization, aerobic performance is still significantly diminished compared to sea level conditions (Brothers, 2007; Brothers, 2008). To date, it is unknown the exact amount of decrement associated various stages in a hypobaric hypoxic environment.

The best, most similar practical application of the scientific literature to adjust endurance run times based on altitude is the NCAA. The NCAA adjusts national championship qualifying times

based on the elevation of the qualifying location. For instance, for the NCAA 1 mile run held at USAFA in 2010, the men's Division I qualifying time was increased by 9.51 (3.58%) seconds from a sea-level qualifying time of 4:15.51 seconds. This adjustment is made for all competitors regardless of the elevation of their home university (acclimatized or not). The NCAA's formula is based on scientific research and analyses of historical NCAA race data and was created to ensure maximal fairness in comparing endurance run times at various elevations. This also should be the goal of the Air Force Fitness Test 1.5 mile run - to ensure maximal fairness in comparing endurance run times at various altitudes. Otherwise, Air Force members testing at lower elevations are given an unfair advantage within the Air Force and its promotion system. There is no basis in the scientific literature or in practical application that caused the Air Force to do away with the altitude adjustment while the NCAA continues to use it.

In addition, research performed by the Army supports completing this research. Technical Bulletin, Medical 505 states "Some physical deconditioning will occur at altitudes since exercise training intensity is reduced. Soldiers will likely require longer times to complete the Army Physical Fitness Test (APFT) 2-mile run at and above 1,400 m (4,593 ft)." (TB 505, 2010) Additionally, it states that "prolonged physical performance at a given altitude is improved by acclimatization but will remain impaired relative to sea level at elevations above 1,000 m (3,281 ft). Reductions in VO_2 max are measurable at elevations as low as 580 m (1,903 ft), curvilinearly related to elevation, and nearly 80 percent reduced from sea level at the highest elevation on earth (Mount Everest, 8,848 m (29,029 ft)). These Army studies demonstrate the lengthy acclimatization time required as well as the effects of altitude. They also agree with previous 'short-term' (less than a month) research at altitude. Faulkner et al. (1967) found a 5-6% decrease in performance at 7,500 feet for events over 2

minutes duration, while others have found a 9-13% reduction in sea level VO_2 max after 20 days at moderate altitude residence (Bailey, 1998; Mairbaurl, 1986).

More research is required at moderate altitude to quantify the difference that our previous research (Brothers, 2008) suggests in that complete acclimatization will not allow an individual to return to their normobaric VO_2 max values. This study will investigate if a significant difference in aerobic performance exists between moderate altitude and sea level and, if it does exist, to what extent.

METHODS

Participants

Fifty-five, fully informed, non-smoking male and female subjects participated in this within-subjects design research study and signed an informed consent document (ICD). Three male subjects dropped out after completing several tests for reasons beyond the researcher's control. Partial data from these subjects were included in the analyses. We aimed to gather complete data on at least 45 subjects, thus providing sufficient statistical power (81.2) for the comparisons of interest. Recruitment of 55 participants allowed us to maintain our desired statistical power while accounting for possible participant attrition. Civilian and military members were recruited. All active duty personnel had supervisor permission to participate in the study during normal duty hours.

Inclusion criteria included the following; body mass indexes (BMI) less than 30, subjects regularly ran > 5 miles per week or exercised aerobically more than 30 minutes 3 times per week, and were willing and able to perform moderate to strenuous exercise. Participants had to be living in the Colorado Springs area for at least 6 weeks to allow for any acclimatization since the earliest any Air Force member would be required to test is six weeks after a PCS to a base located at moderate altitude (Air Force Fitness Program).

The study ran between Jan 2011 to Sept 2011. The total time requirement for each subject was approximately two hours. Testing sessions were completed in the following order:

30 min – ICD review and Maximum oxygen uptake treadmill (VO_2 max) test introduction

30 min –VO_2 max and Whole Body Dual X-Ray Absorptiometry (DXA) tests

30 min – 1.5 run in first environmental condition only knowing completed distance during the run. (randomized)

30 min – 1.5 run in opposite environmental condition only knowing distance completed distance during the run. (randomized)

Facilities

United States Air Force Academy Human Performance Laboratory

Experimental Design

The study was a simple within-subjects design. Each subject completed two 1.5 mile runs, one at 7,200 ft (ALT) and one at simulated 850 ft (~26% O_2) (SL). The Colorado Altitude Tent (CAT) (Figure 1) used was a normobaric hyperoxic tent which allows oxygen levels to be increased from ~21% O_2 to ~26% O_2. The partial pressure of oxygen (ppO_2) at 7,200 ft (Human Performance Laboratory altitude) was approximately 122 mmHg (580 mmHg * 20.93%), while ppO_2 at simulated SL was approximately 150.8 mmHg (580 mmHg * 26%) which compares favorably to the ppO2 at sea level which is 159.6 (760 mmHg * 20.93%). Order of the running environments was randomized using a randomization table. There was at least 24 hours between all running tests, including the VO_2 max. Fifty-five, fully informed non-smoking male and female, subjects participated in this within-subjects design research study.

Figure 1 – USAFA HPL Normobaric Hyperoxic Colorado Altitude Tent (CAT)

Test Procedures

Prior to participating in the study, each subject was given a brief explanation of the research procedures. The subjects were then asked to sign an informed consent document (ICD) and complete a medical questionnaire. The subjects were then briefed and fitted for the VO_2 max test. To become familiar with the test and running with a mask on each subject completed the first two stages (Figure 2) of the VO_2 max test. Subjects then returned to the USAFA Human Performance Laboratory at least one day later to complete the VO_2 max and DXA tests. At least one day later, the subjects returned to run the first 1.5 mile run. At least one day later, but no more than 5 days, the subject returned to the lab to run their 2nd 1.5 mile test in the opposite environmental condition. The subjects were blinded to the running environment to the best of

our ability. Following the last testing session, the subjects completed an exit interview and reviewed their results. The following is an explanation of the tests.

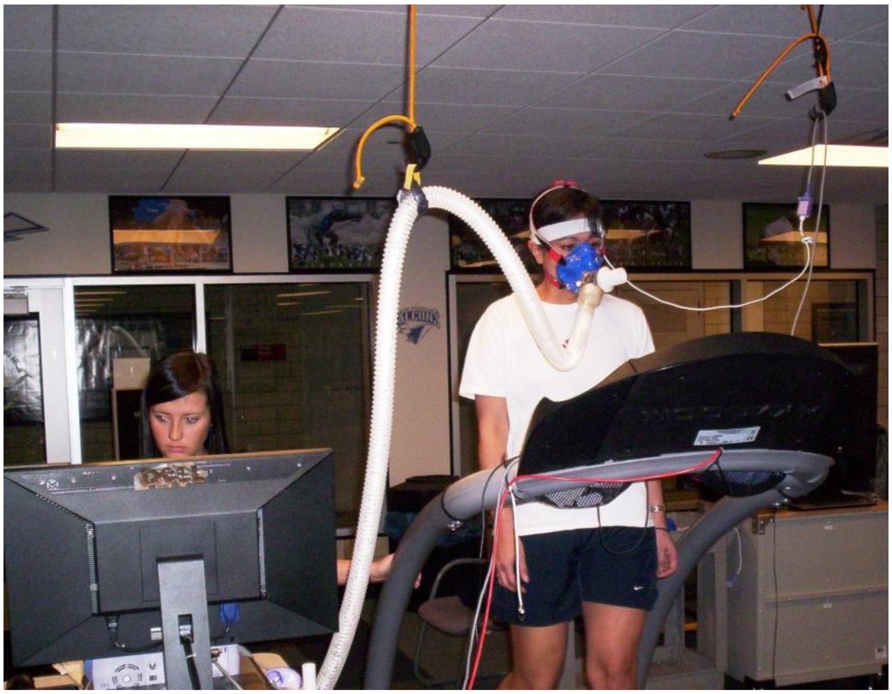

Figure 2 – Maximal Oxygen Update Treadmill (VO2 max) Test

Maximal Oxygen Uptake Treadmill (VO_2 max) Test

The maximal oxygen uptake protocol (table 1) was conducted on the Woodway DESMO Treadmill (Woodway, Waukesha, WI, USA) at lab altitude (7,200 feet). Each subject was fitted with a head gear harness and a facemask to collect expired air for the Parvo Medics' TrueOne 2400 metabolic measurement system (ParvoMedics, Sandy, UT). Subjects were required to wear a Polar heart rate monitor chest transmitter to measure heart rate response and a forehead sensor was attached for hemoglobin oxygen saturation (SaO_2) determination via pulse oximetery. Once prepped, the subjects were asked to stand for a one-minute rest period to ensure all the recording data was being obtained accurately. Following this rest period, the subjects had a two-minute walking stage at 2.0 mph. Upon completion of the two-minute walk, the treadmill belt gradually

increased to a running speed of 7.0 mph (male) or 6.0 mph (female) at 0% grade for two minutes. At the beginning of the 6th minute, the grade increased to 2% and the subjects continued to run at 7.0 or 6.0 mph and 2% for one minute. Following this stage, the treadmill grade increased in increments 2% each minute for the next four minutes. After minute 10, the treadmill grade only increased by 1% each minute until the end of the test. The subjects were asked to continue running until they were no longer capable. Once the subjects reached volitional fatigue, they straddled the treadmill belt and the treadmill slowed to a 2 mph pace at 0% grade. The subjects then started an active recovery until their heart-rate dropped below 120 bpm. Upon completion of the test, several post reports indicating heart rate (HR), VO_2 max in $L \cdot min^{-1}$ and $mL \cdot kg^{-1} \cdot min^{-1}$, RER (respiratory exchange ratio), and ventilatory threshold were produced. This test was completed once by all subjects.

Table 1 - Treadmill Protocol

Test Time (min)	Stage Time (min)	Speed (mph)	Grade (%)	Activity
0-1	1:00	0	0	Standing
2-3	2:00	2.0	0	Walking
4-5	2:00	7.0 m, 6.0 f	0	Running
6	1:00	7.0 m, 6.0 f	2	Running
7	1:00	7.0 m, 6.0 f	4	Running
8	1:00	7.0 m, 6.0 f	6	Running
9	1:00	7.0 m, 6.0 f	8	Running
10	1:00	7.0 m, 6.0 f	10	Running
11	1:00	7.0 m, 6.0 f	11	Running
12	1:00	7.0 m, 6.0 f	12	Running
13	1:00	7.0 m, 6.0 f	13	Running
14	1:00	7.0 m, 6.0 f	14	Running
End of Test	Until HR <120	2.0	0	Active Recovery

Whole Body Dual X-Ray Absorptiometry (DXA) Body Composition Test

The Whole Body Dual X-Ray Absorptiometry (DXA) test was performed on a low-dose whole-body x-ray on a GE (General Electric) Lunar Prodigy scanner. This test was only completed once and helped described the subject's characteristics for body composition including percent body fat and fat-free mass. Safety material provided by GE calculates that the skin entrance dose of one total body scan was 0.4 centigrey over 274 seconds. The risk of DXA scan radiation was equivalent to that of a one hour of flight at 30,000 feet and much less than that of a chest x-ray. Human Performance Laboratory operators were fully trained on using the DXA scanner.

1.5 Mile run

Both 1.5 mile run tests (ALT & SL) were accomplished on a Woodway DEMSO treadmill located inside the CAT (Figure 1). The DEMSO treadmill has the Air Force 1.5 mile run preprogrammed into its control panel. The subjects were fitted with a heart rate strap and a forehead sensor for hemoglobin oxygen saturation (SaO_2) determination and then allowed to warm-up as much as they normally would before any run. The subjects then began the test. During the test, the subjects were able to see the distance completed and were in complete control of the treadmill speed for the entire test. The subjects were able to adjust their speed based on how they were feeling, just as if they were on an outdoor 1.5 mile course. The treadmill speed, elapsed time, and heart rate displays were covered so as not to influence the subjects' running speed. Heart rate, SaO_2, rate of perceived exertion (RPE), and test time were monitored and recorded by researchers at each quarter mile point. During all 1.5 mile runs, the high performance CAT air units were turned on, but O_2 may or may not have been flowing into the tent. This blinded the subjects to the environmental condition they were running in.

Statistical Analyses

Descriptive statistics were used to provide the mean ± SD for subject demographics. Physiological variables results between conditions were analyzed using an ANOVA. Complete data (55 subjects) is included in the descriptive and VO_2 max data, while partial data (52 subjects) is included in the 1.5 mile test results.

RESULTS

Descriptives

Table 2 summarizes the means and standard deviations for body composition (DXA), age, height, and weight for males, females, and all subjects. Percent body fat ranged from 5.8% to 32.9%. Ages ranged from 20 to 44 years. Height and weight ranged from 61.5 to 80.8 inches and 102.1 to 239.2 pounds respectively.

Table 2 - Subject Demographics

	n	DXA (%BF)	Age (yrs)	Height (in)	Weight (lbs)
Males	38	16.4 ± 7.6	32.3 ± 6.5	71.7 ± 3.1	173 ± 24
Females	17	24.9 ± 4.7	33.6 ± 6.9	64.7 ± 2.2	132 ± 18
Total	55	19.0 ± 7.9	32.7 ± 6.6	69.5 ± 4.4	160 ± 29

The average maximal VO2's for males, females and all subjects combined are shown in Figure 3. The maximal VO_2 ranged from 35.2 to 64.8 $mL \cdot kg^{-1} \cdot min^{-1}$.

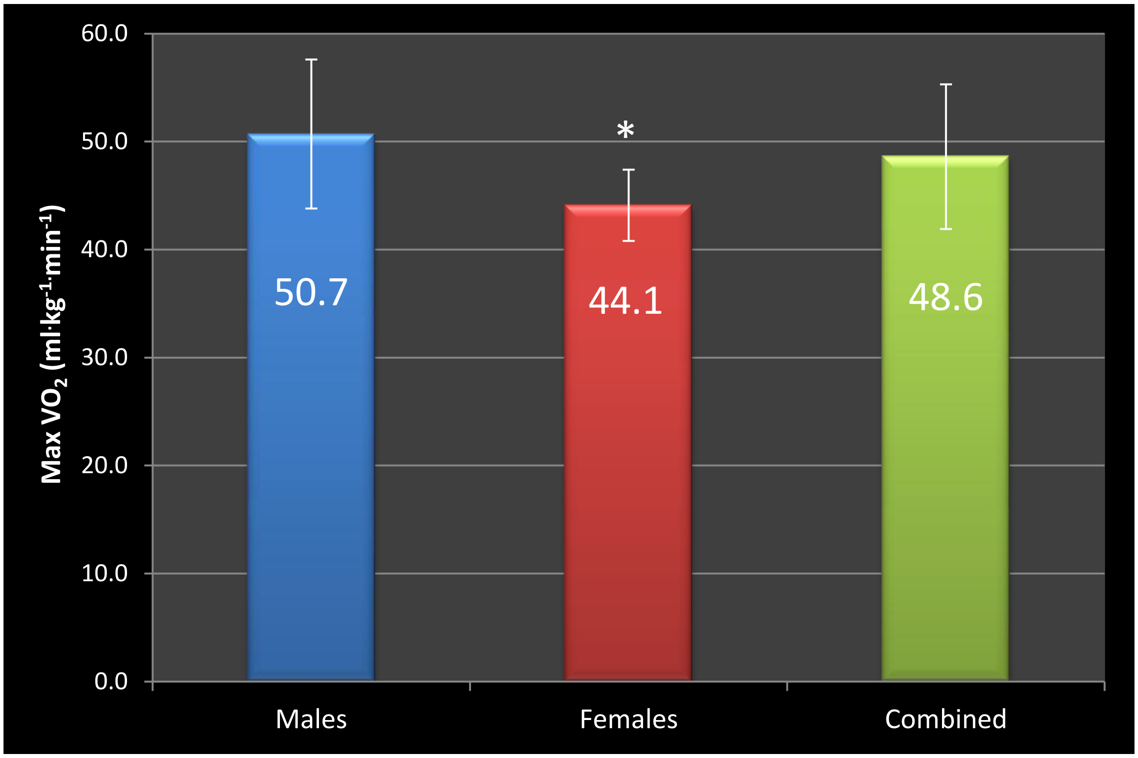

Figure 3 - VO_2 Max results for Male, Female and All Subjects. * $p<0.001$ between Male and Female VO_2's.

Maximal Oxygen Uptake (VO_2 max) and Predicted VO_2 Max Results.

The relationships between the actual VO_2 max values and the predicted VO_2 max values at 7,200 and simulated 850 feet conditions are displayed in Figure 4. Predicted VO_2 max values were derived from 1.5 mile run times using the following the VO_2 max calculator (Griffing, et al., 2011) based on Dr. Kenneth Coopers prediction equation.

Both predicted VO_2 max values correlate strongly with the treadmill VO_2 max; however, the predicted values at ALT (R=.84) (Figure 5) show a slightly stronger correlation to true VO_2 max as compared to the predicted values at SL (R=.82) (Figure 6).

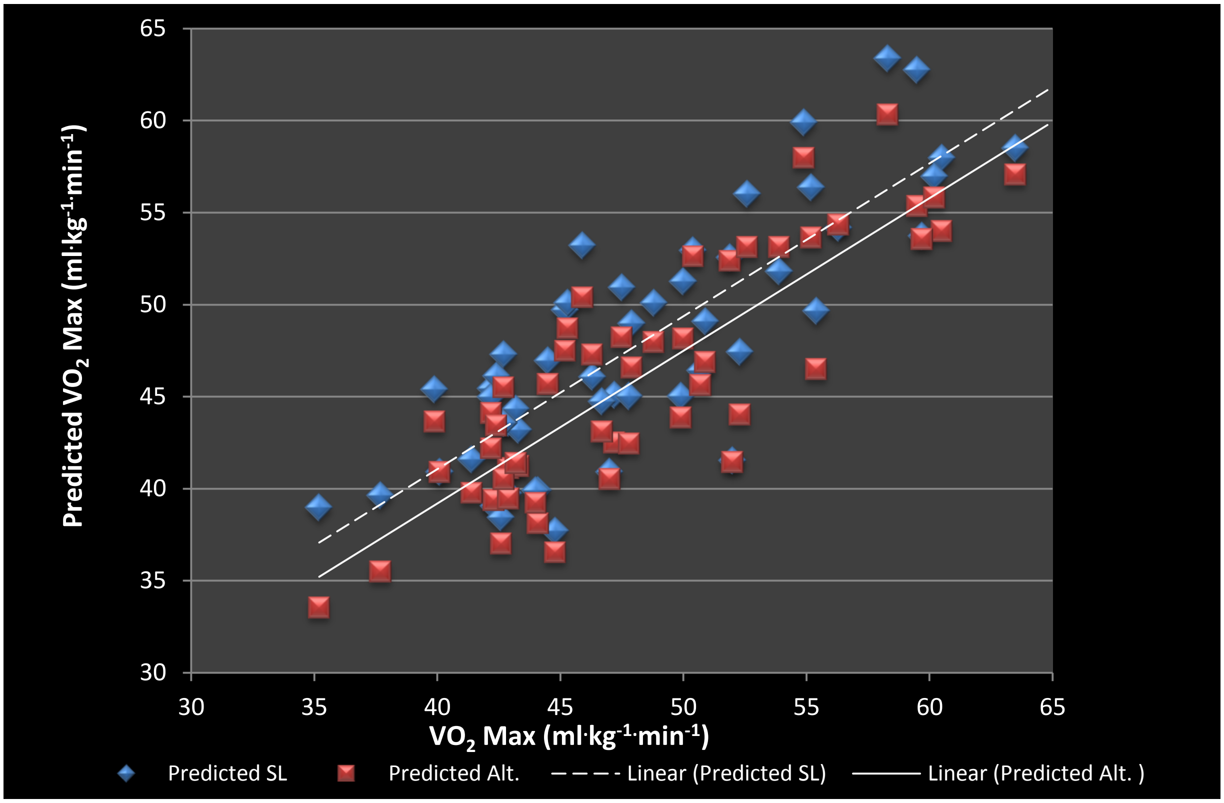

Figure 4 - Illustrates the differences between predicted VO_2 Max values based on 1.5 mile run times at ALT and SL conditions. The actual VO_2 Max values indicated by the points are shown in correlation to predictions of VO_2 Max by the linear lines.

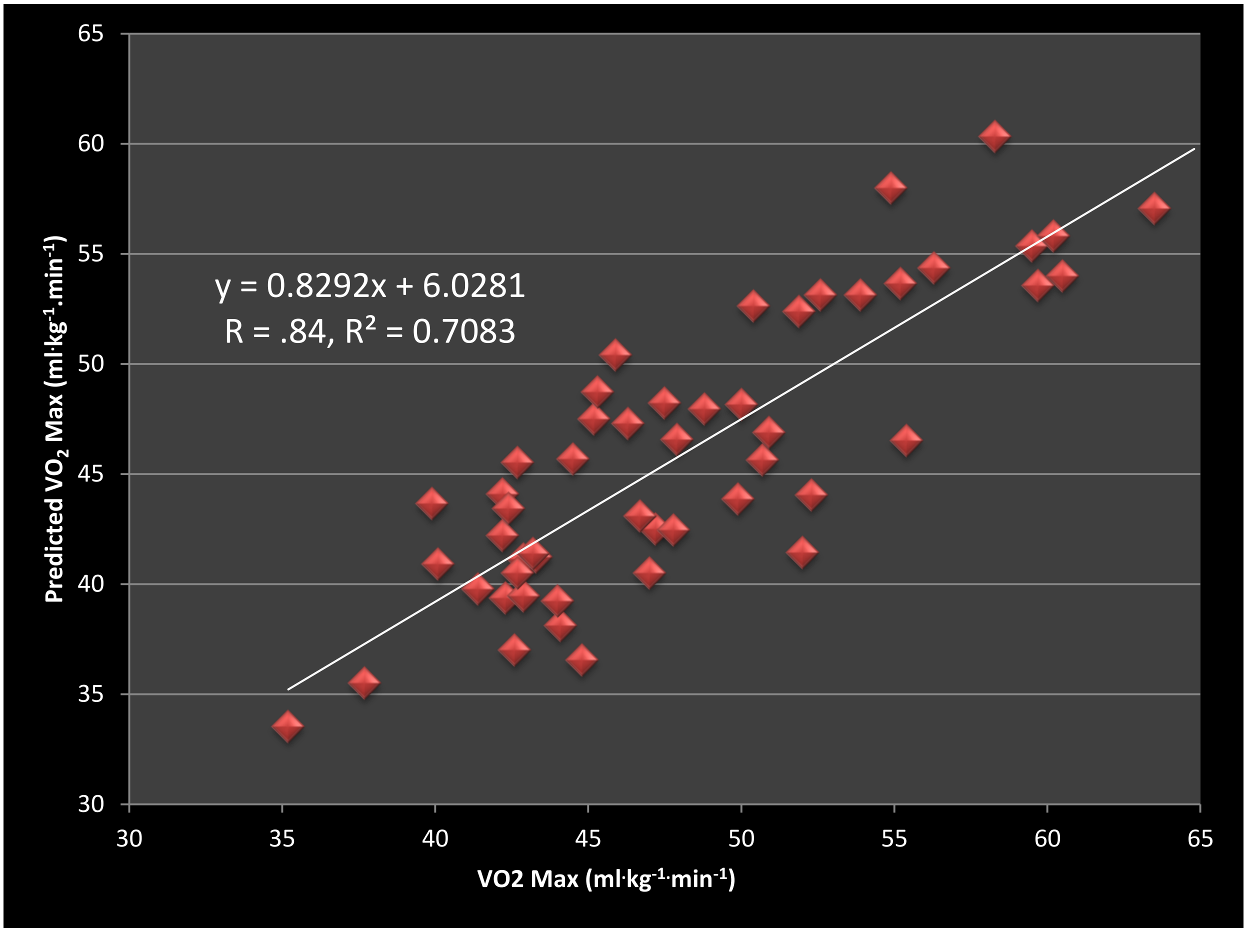

Figure 5 - Actual VO_2 Max vs Predicted VO_2 Max at ALT (7,200 Feet). Illustrates the differences between actual and predicted VO_2 Max values based on 1.5 mile run times in altitude conditions.

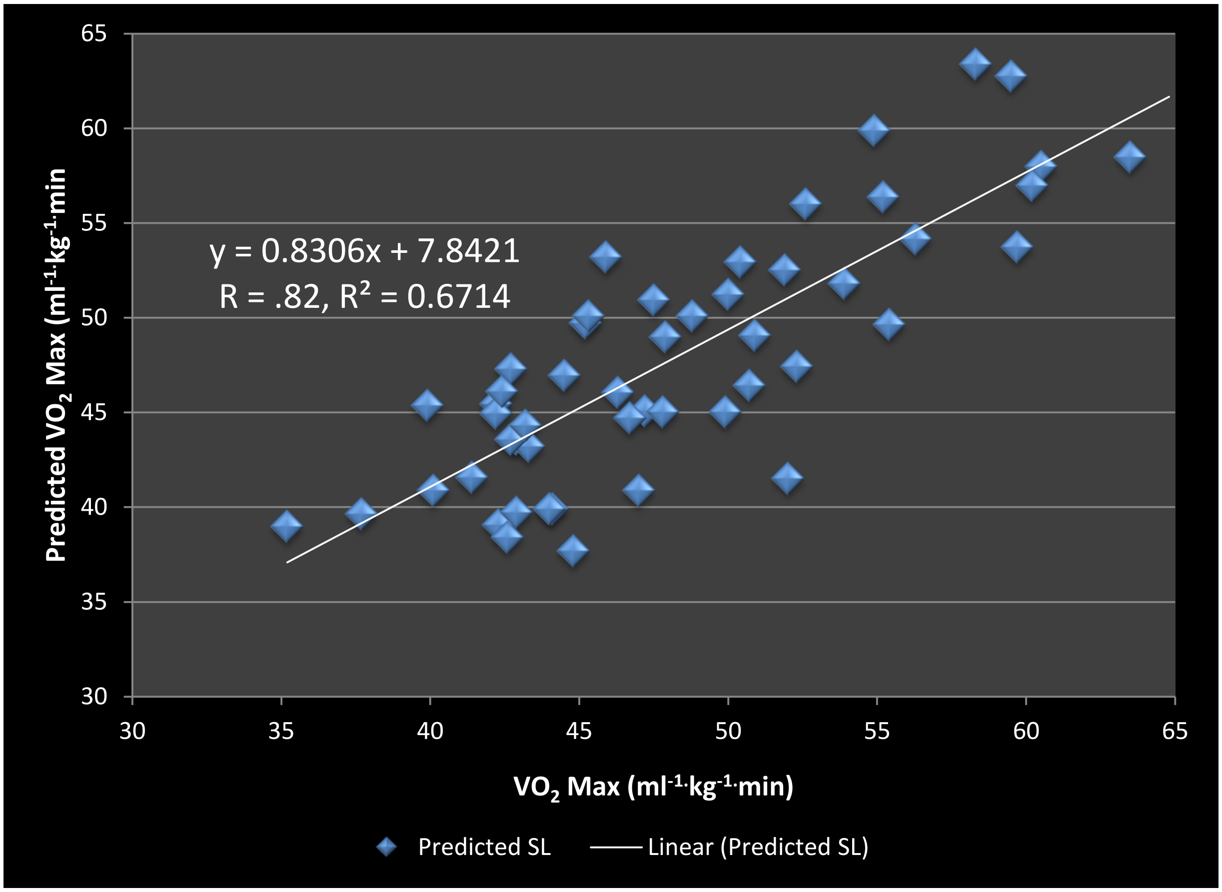

Figure 6 - VO_2 Max vs Predicted VO_2 Max at Simulated SL (850 Feet). Illustrates the differences between predicted VO_2 Max values based on 1.5 mile run times in simulated 850 feet.

1.5 Mile Runs Results

A 30.6 seconds, or 4.4%, significant difference ($p<.001$) was observed between the ALT and SL 1.5 mile runs (Figure 7). There were minimal differences between the runs for the first half of the test (0-.75 miles). During the second half of the test, ALT run times began to lag behind the SL runs (Figure 8) with the significant difference observed between runs at the 1.5 mile point. A significant correlation ($p<.001$) of .96 was seen between the two runs, with the ALT run being consistently slower within individuals (Figure 9).

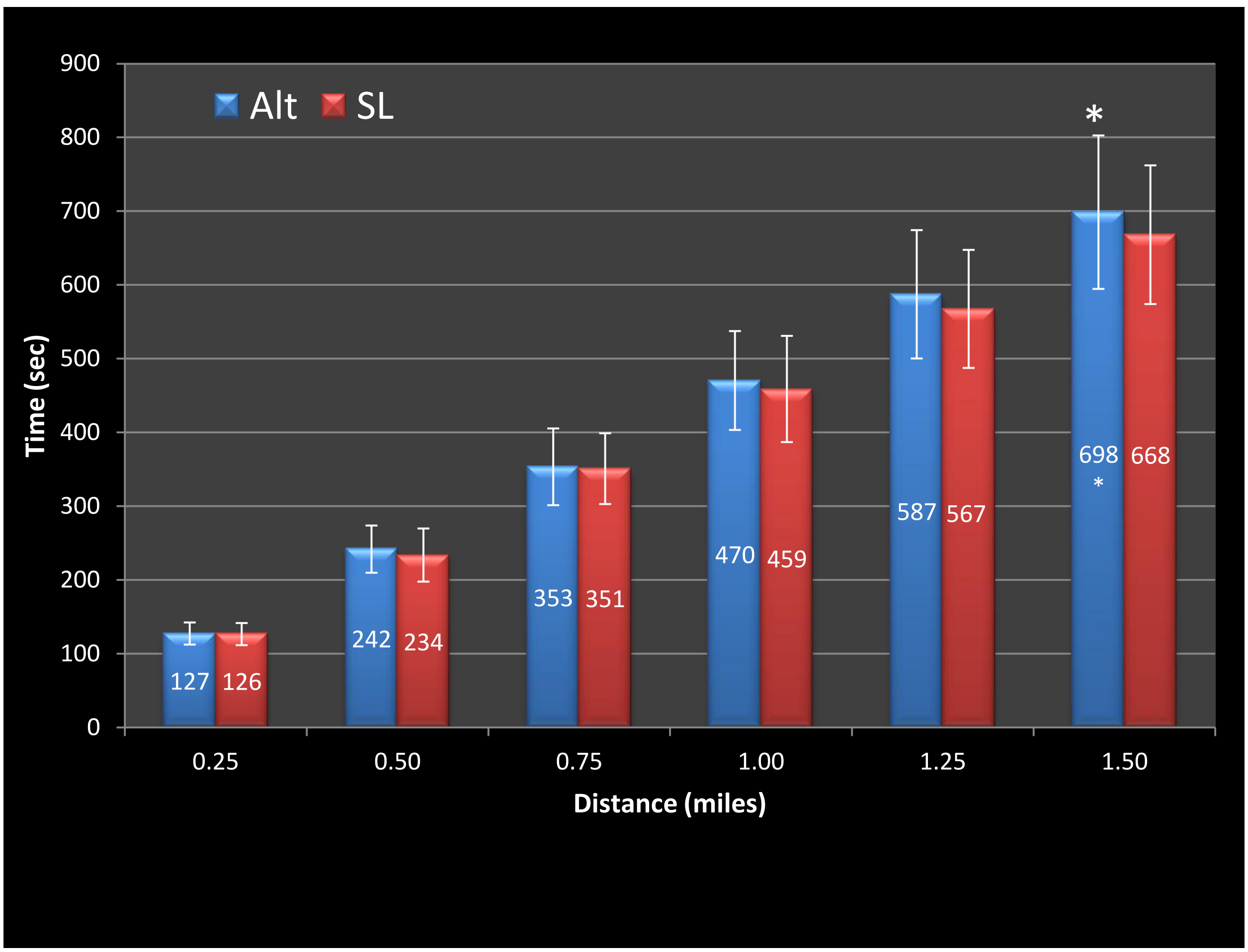

Figure 7 - 1.5 Mile Run Times at ALT and SL. Illustrates the time differences between 1.5 mile run times at ALT and SL conditions at quarter mile increments. * p<0.001 between ALT and SL testing at 1.5 miles.

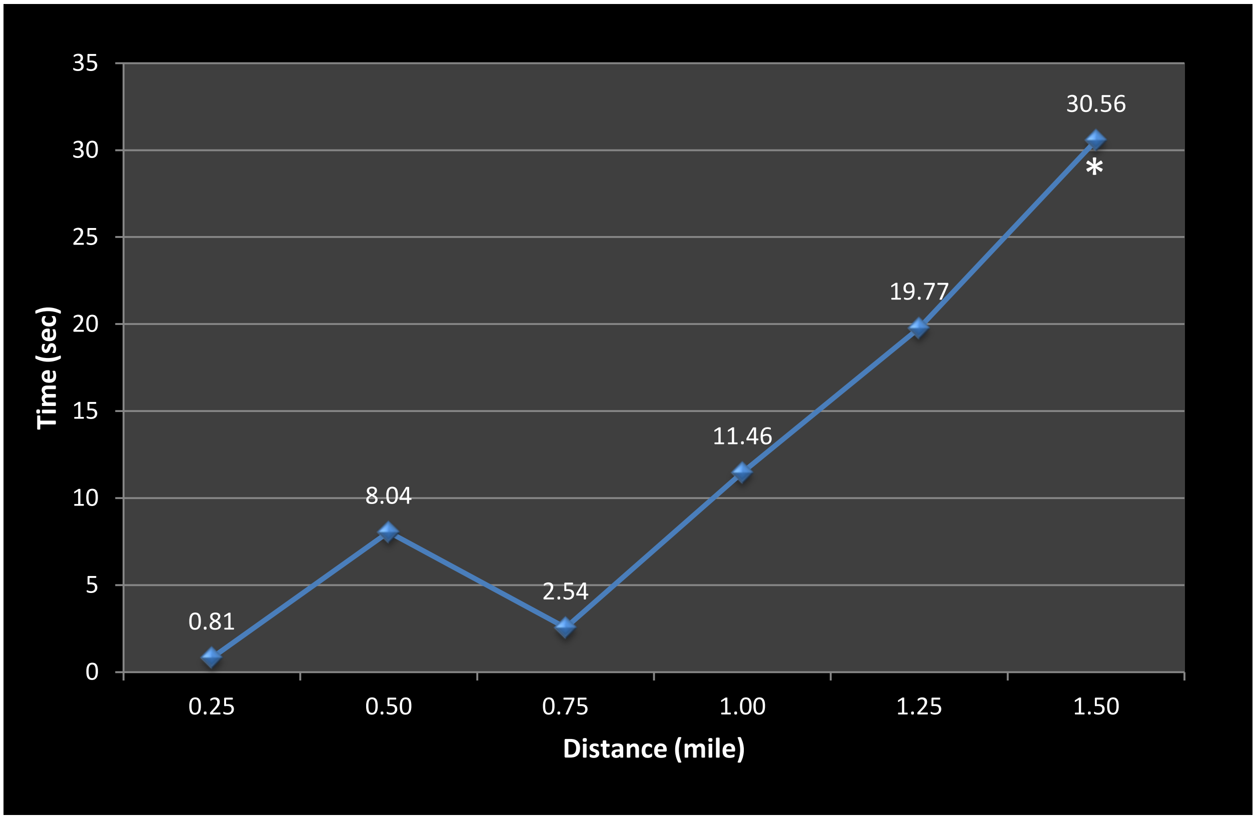

Figure 8 - Illustrates the differences between ALT and SL run times at quarter mile intervals. * A significant difference (p<.001) was observed between the runs at the end of the test (1.5 mile point).

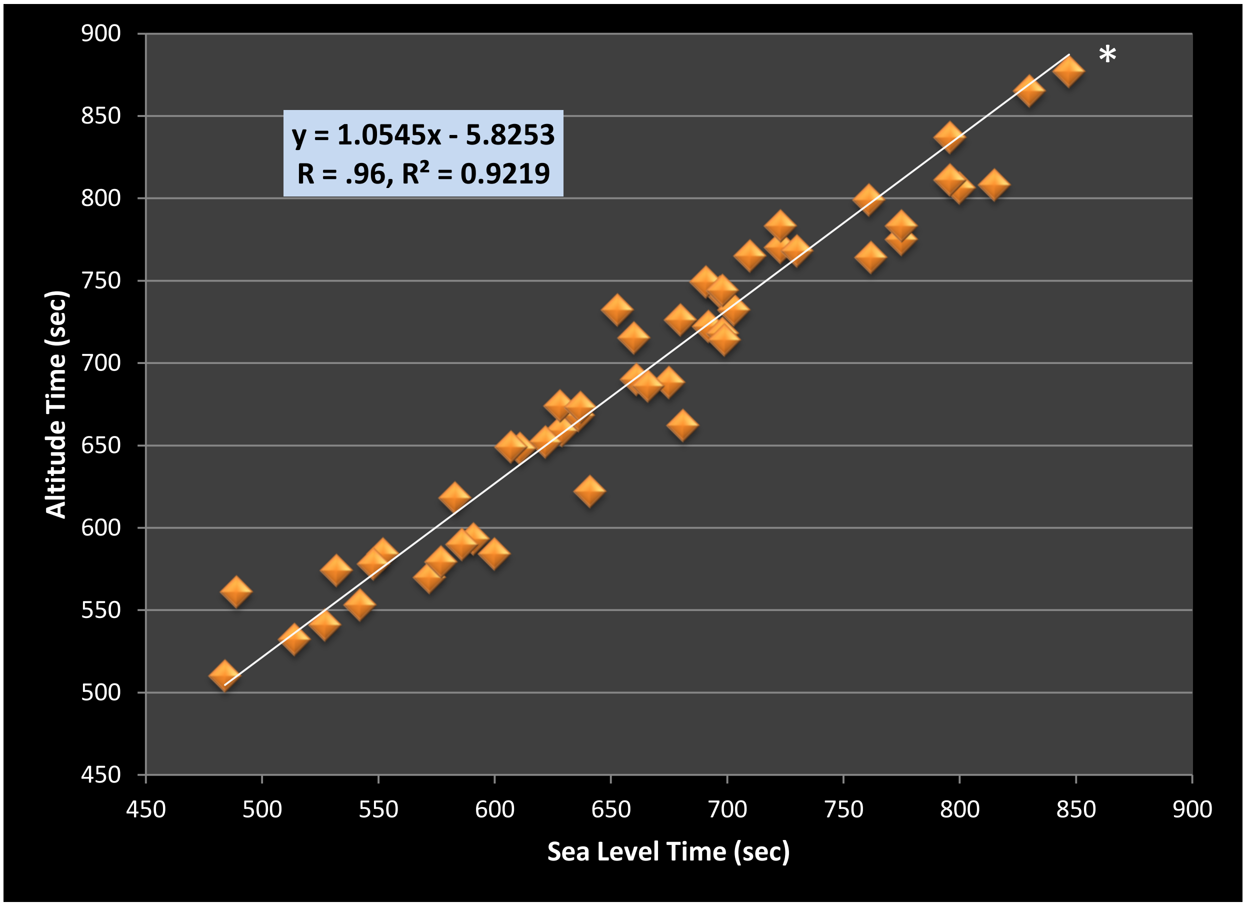

Figure 9 – Correlation in run times between ALT and SL. * A significant correlation of .96 ($p<.001$) was seen between the two runs.

During both runs, heart rates and rate of perceived exertions (RPE) were recorded at each quarter mile interval. There was no difference in heart rate response between tests during the first mile, but significantly higher SL heart rates were seen at the 1.25 mile interval and at the end of the run ($p<0.05$) (Figure 10). Significant differences in RPE's were observed at the .75 and 1.00 ($p<0.05$) mile run intervals (Figure 11).

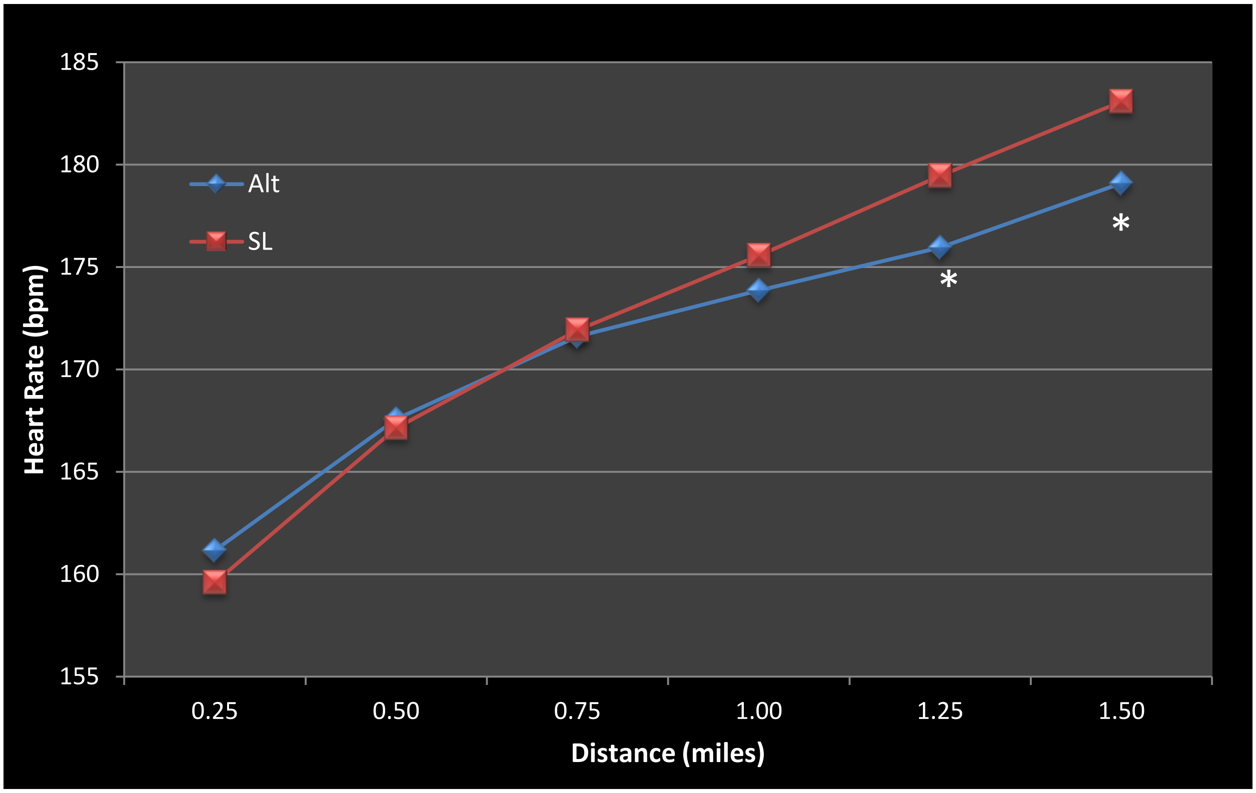

Figure 10 - Heart Rates during 1.5 mile at ALT and SL. * A significant difference ($p<0.05$) was observed between the runs at the 1.25 and 1.5 mile points.

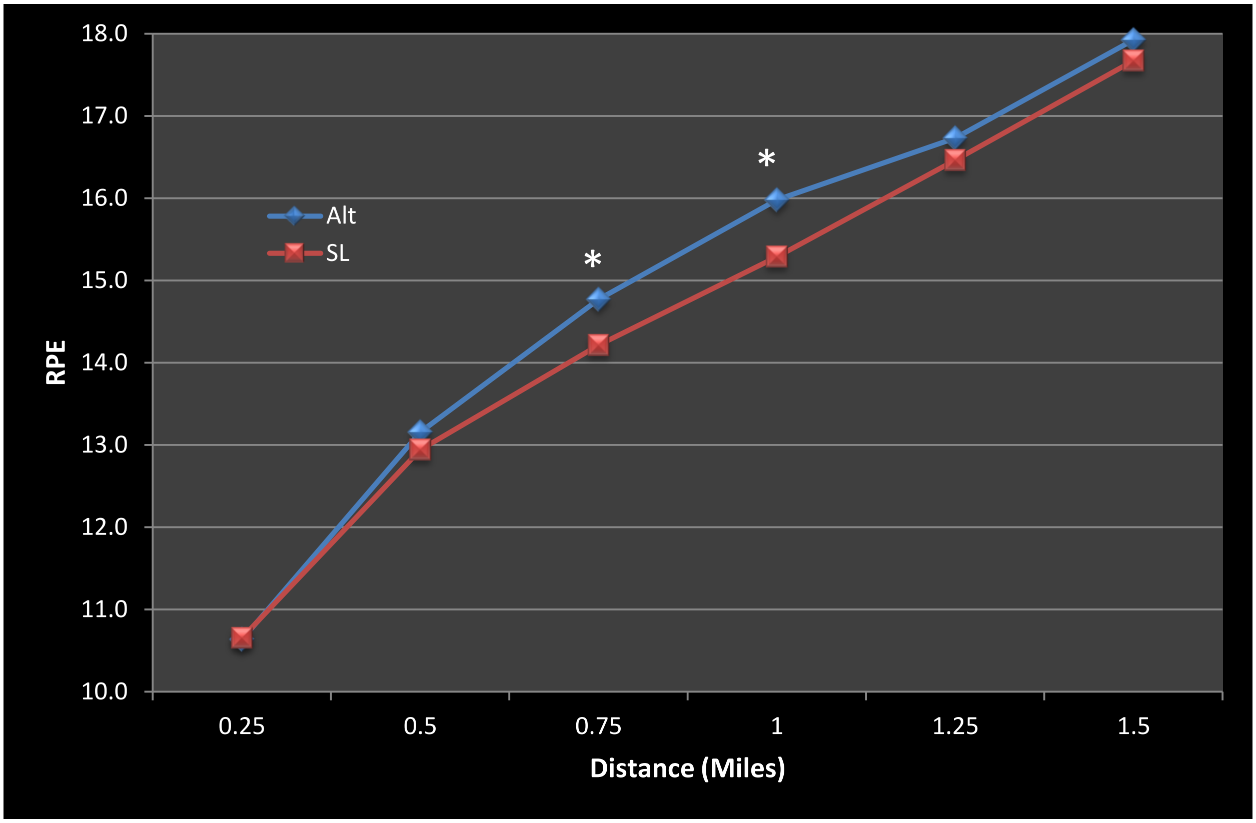

Figure 11 – RPE's during 1.5 mile runs at ALT and SL. Significant differences (p<0.05) were seen between runs at the .75 and 1.0 mile intervals.

DISCUSSION

The purpose of this study was to investigate if a significant difference in aerobic performance exists between moderate altitude and sea level and, if it does exist, to what extent. The results will be used to provide evidence that a time adjustment for the Air Force Fitness test for bases >5000 ft is justified. Out of the 52 subjects that completed both 1.5 mile runs, 18 had been residing at the USAFA Academy or in Colorado Springs, Colorado for less than one year. Brother et al. (2008) found that complete acclimatization at moderate altitude is a 4-6+ month process and even then, cardio-respiratory fitness is still impaired to that of sea level conditions. Within these 18 subjects (Figure 12), those who resided longer at moderate altitude (Colorado Springs) showed less of a

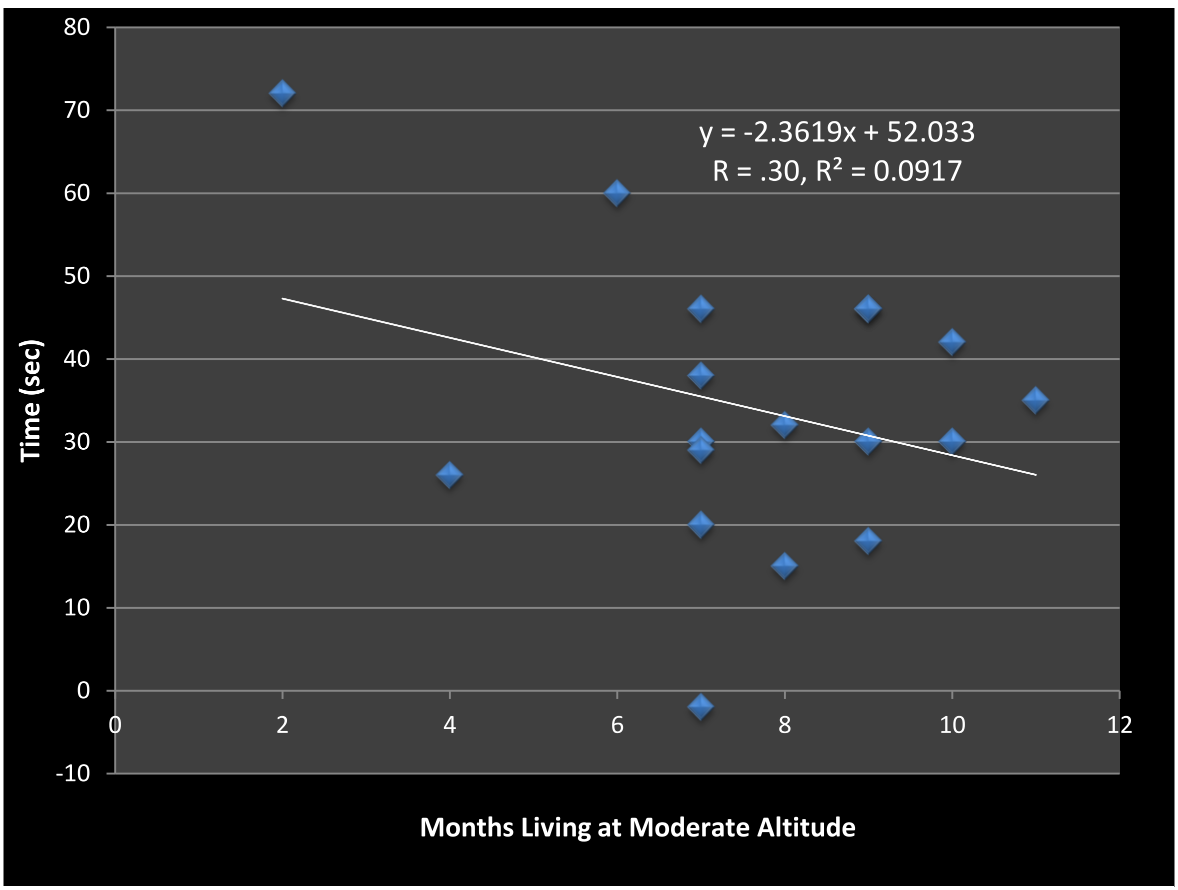

Figure 12 - Time Differences correlated to the Length of Time Living at Moderate Altitude

difference between the runs at ALT and SL, although there was a high variability. This individual acclimatization variability agrees with Brothers (2008) showing that individuals respond differently when exposed to moderate altitudes . When looking closer at the results of these 18 subjects, the average time difference increased to 34.1 seconds; a 3.5 second increase compared to all subjects, with 11 of the 18 subjects that lived at for less than one year at moderate altitude having run time differences equal to or greater than 30 seconds.

From the data collected, a 30.6 second difference between the two 1.5 mile runs was observed; sea level conditions resulted in faster run times for most subjects with the exception of five subjects that performed better at altitude (Figure 13). These five individuals performed an

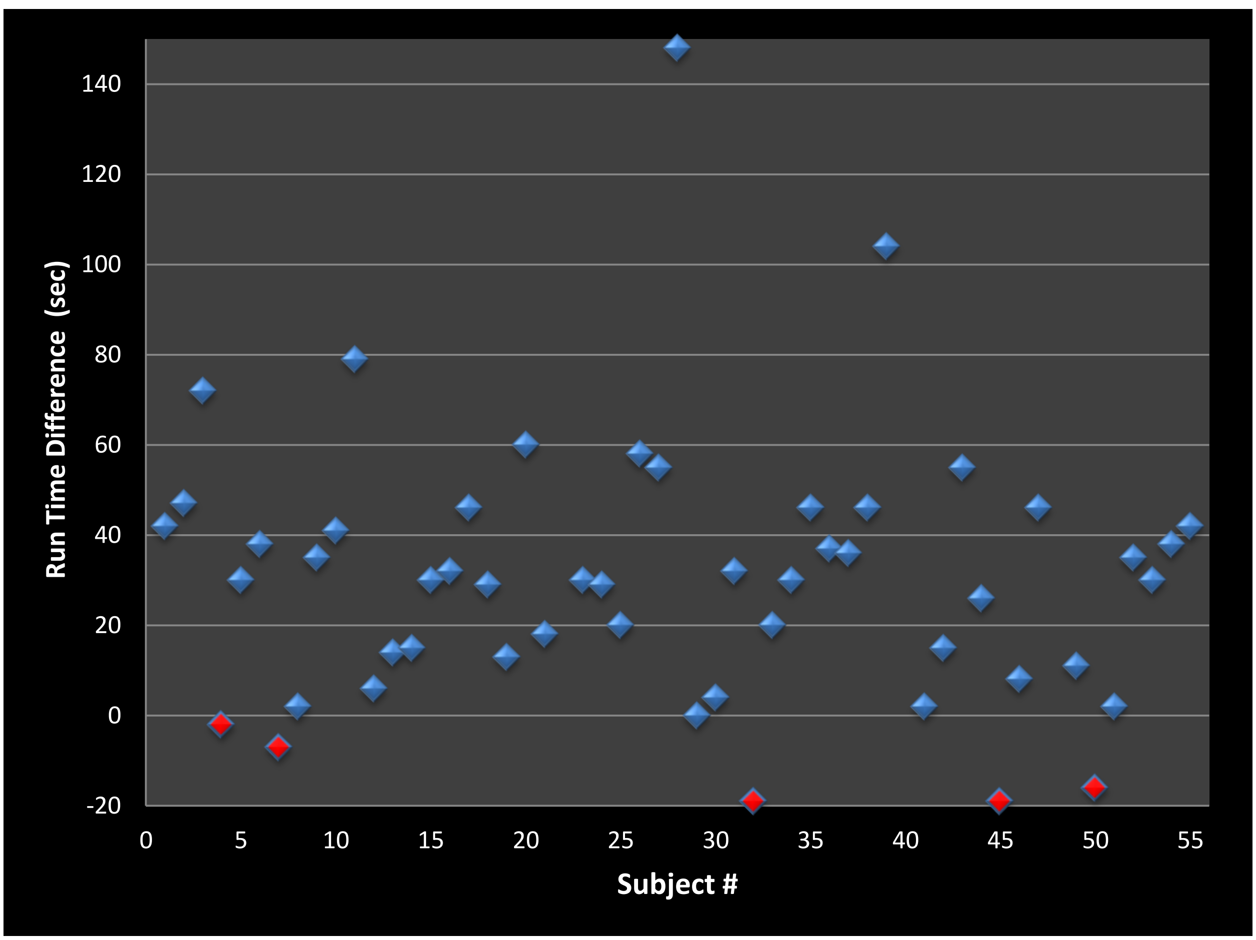

Figure 13 - Running Time Differences between ALT and SL for all Subjects

average of 12.6 seconds better at ALT than SL with run differences ranging from 2 to 19 seconds. There were no common phenotypes associated with these five subjects, other than that they were all male subjects. The VO_2 max for this group of 5 subjects averaged 48.8 $mL \cdot kg^{-1} . min^{-1}$ ranging from 42.3 $mL \cdot kg^{-1} \cdot min^{-1}$ to 56.3 $mL \cdot kg^{-1} . min^{-1}$. This average was just slightly lower than the 50.7 $mL \cdot kg^{-1} \cdot min^{-1}$ for all male subjects. The average body fat percentage for these five subjects was slightly higher (17.2%) than all male subjects (16.4%), with a range of 6.6% to 25.2%. None of these five subjects were born at moderate altitude and they all had moved from a sea level location prior to being stationed at the Academy. These individuals had lived at moderate altitude for 7, 19, 20, 34, and 67 months averaging 29 months. The lowest time difference between runs was 2 seconds, recorded by the subject that lived at moderate altitude for 7 months. The greatest time difference of 19 seconds was seen in two subjects. These two subjects had resided at moderate altitude for 67 and 34 months.

When the run times were broken down by gender, the same trends were seen (Figure 14). There were significant differences in run times at all six intervals when the female times were

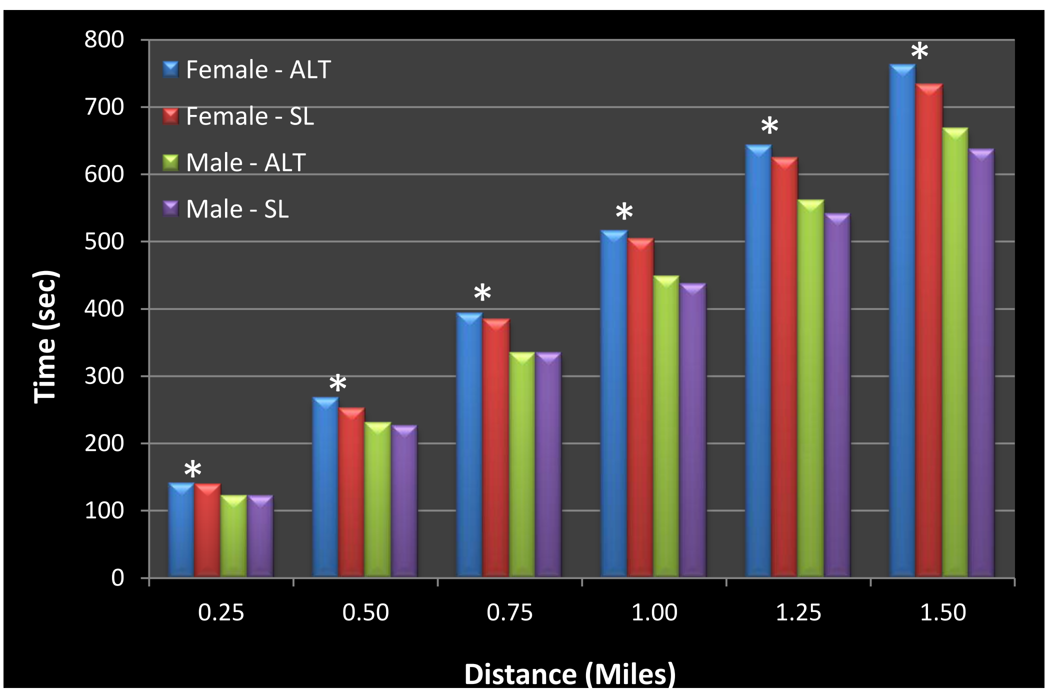

Figure 14 - Time during the 1.5 Mile Runs for Male and Females at SL and ALT. *Significant differences ($p<0.05$) were seen between genders at each interval.

compared to male times, but no differences in run times at ALT and SL were observed for either gender at any of the .25 mile running intervals (Figure 15).

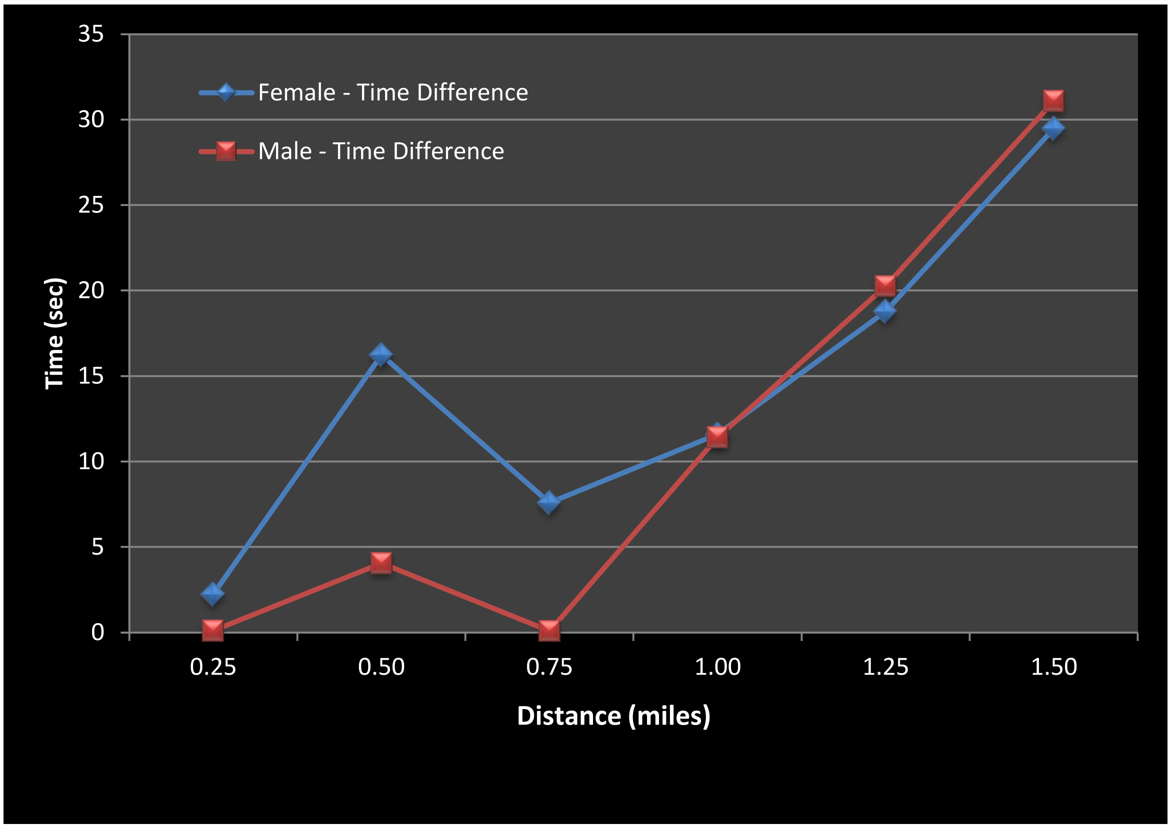

Figure 15 - Time Differences for Male and Female Subjects During the 1.5 Mile Run

The sequence of ALT and SL runs was randomized and resulted with 26 subjects having their first run at ALT and 26 subjects having their first run at SL (Figure 16). Both groups

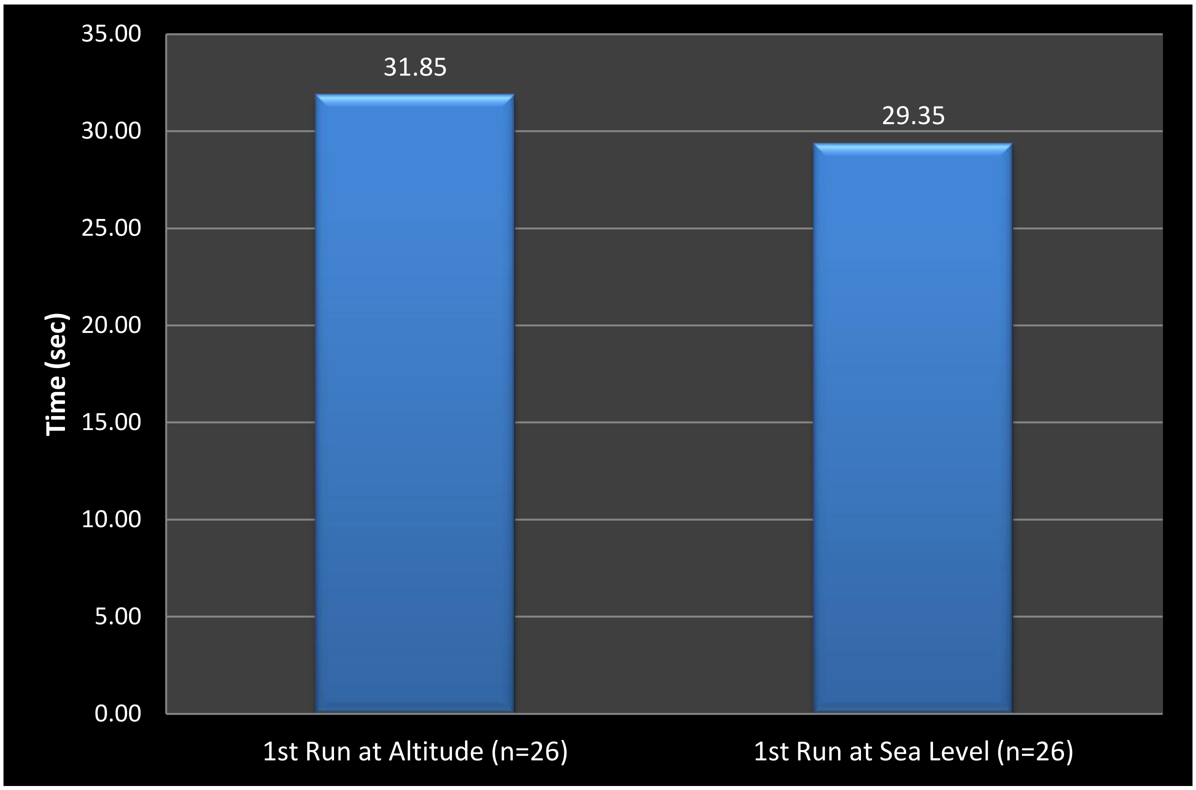

Figure 16 - Differences between 1.5 miles based on 1st run environment

averaged slower runs at ALT, but there was no significant difference (p=.76) based on the environment in which the first 1.5 mile run was accomplished.

The trends we saw with heart rates (HR) responses as well as with ratings of perceived exertion (RPE) during both runs were expected. Since training intensities are reduced at altitude (TB 505, 2010), it could be suggested that this is the reason higher HR's at sea level. Even though the subjects felt they worked harder at altitude, as demonstrated by RPE, the majority of run times were still faster at sea level.

A 30.6 seconds, or 4.2% decrease in 1.5 mile running times was measured when running at ~850 ft compared to 7,200 ft. These differences were mainly due to a decreased hemoglobin oxygen saturation associated with running at an altitude with a lower ppO_2. At 7,200 feet the atmospheric pressure is appoximately 580 mmHg making the ppO_2 approximately 125 mmHg. At rest or low exercise levels the body is able to compenstate of this reduced O2 partial pressure. But as the exercise session continues or becomes harder the body can not keep up due to the lower oxygen delivery to the muscles.

At rest during the VO_2 max test at moderate altitude, all 55 subjects had normal oxygen saturation level for 7,200 feet altitude, ranging in the 96-97% saturation (Figure 17). At 2.0 mph of the VO_2 max test the oxygen saturations remained close to resting levels, but decreased significantly once the subjects began running and at VO_2 max. All subjects completed at least 7 minutes on the VO_2 max test and at this point the average SaO_2 were down to 88.4% with a slight difference between males (88.8%) and females (87.5%). SaO_2 values continued to decrease at maximal exercise, dropping to 86.7% with the males averaging 87.4% and the females dropping to 86.3%. At these low oxygen saturation levels the cardiovascular delivery system is compromised and less oxygen is available to the muscles (Koskolou & McKenzie 1994, Nielsen, 2003).

We saw the same SaO_2 changes during the ALT 1.5-mile run, but not during the SL runs (Figure 18). Resting SaO_2 was significantly lower at ALT than SL and this trend continued for the remainder of the test. These differences are again due to the lower ppO_2 associated with altitude resulting in lower SaO_2 throughout the ALT runs (Calbet & Lundby, 2009). Once SaO_2 levels dropped below 89% then aerobic performance was impaired.

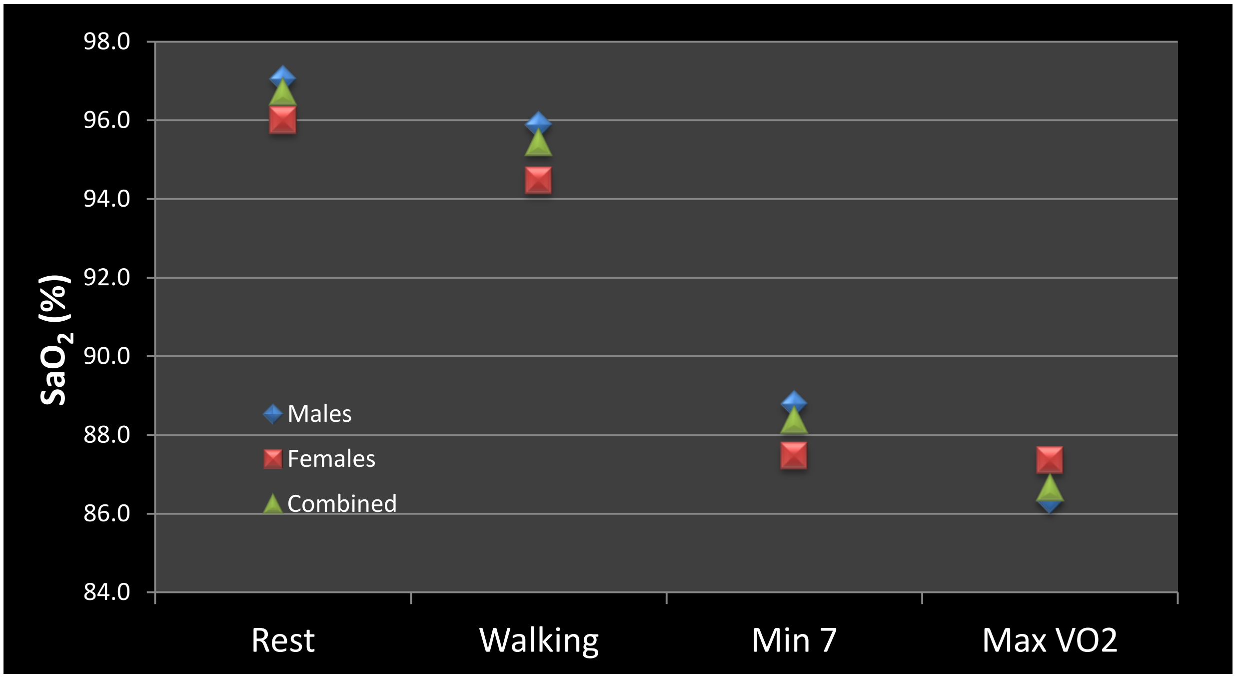

Figure 18 - Oxygen Saturation Changes during the VO_2 max Test Performed at ALT

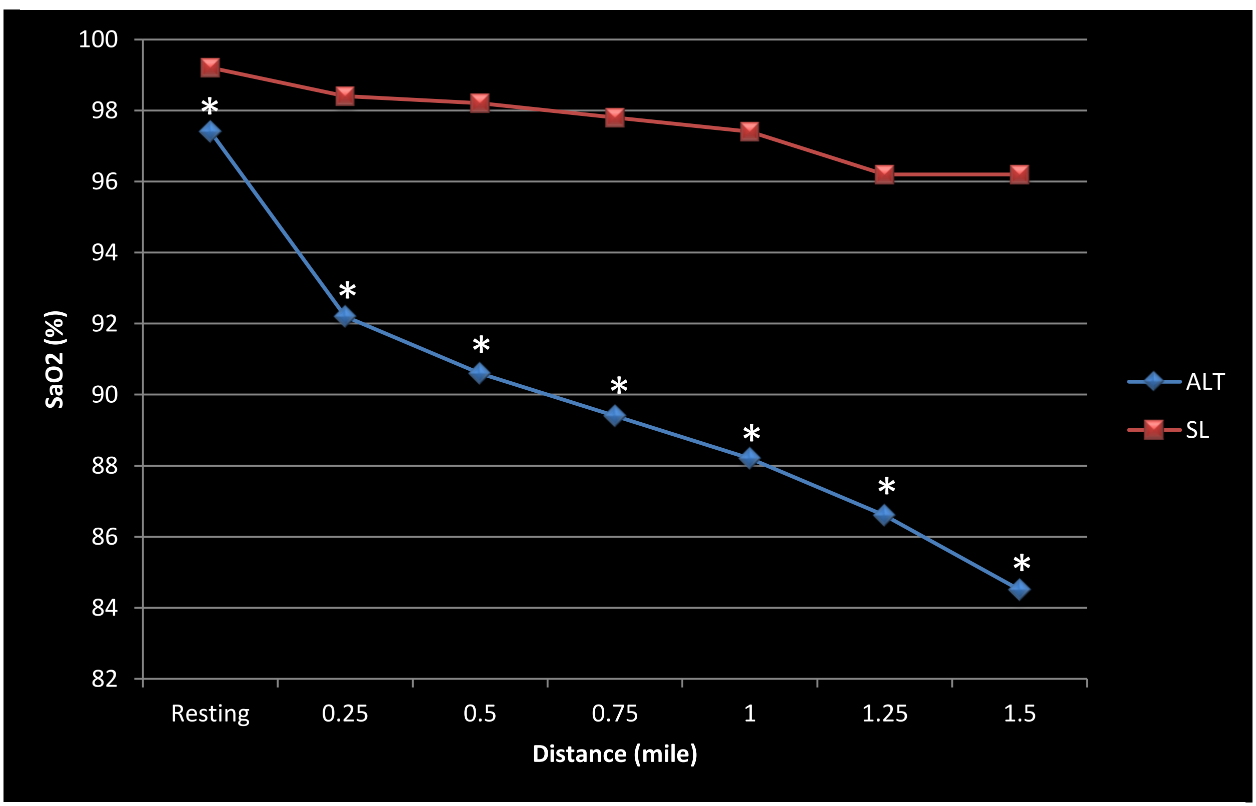

Figure 17 - Oxygen Saturation Changes during the 1.5 Mile Run at SL and ALT.
***Significant differences (p<0.001) were seen between running conditions at each interval.**

CONCLUSION

The average maximal oxygen uptake (VO_2 max) for the subjects was 48.6 $mL \cdot kg^{-1} \cdot min^{-1}$ ranging from 35.2 to 64.8 $mL \cdot kg^{-1} \cdot min^{-1}$. A 30.6 seconds, or 4.4%, significant difference ($p<.001$) was observed between the two 1.5 mile runs when running at ~850 ft compared to 7,200 ft. These differences were mainly due to a decreased hemoglobin oxygen saturation associated with running at altitude with lower O2 partial pressures ($p<.001$). HR and RPE were not significantly different between runs. Our recommendation is that an altitude adjustment for the Air Force fitness test be reinstated for airmen testing at moderate altitude bases

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List of Symbols, Abbreviations, and Acronyms

%BF – percent of body fat
ACSM - American College of Sports Medicine
ANOVA – Analysis of Variance
bpm – Beats per Minute
cm – centimeters
DXA – Dual Energy X-ray Analysis
EE – Environmental Enrichment
EPOC – post-exercise oxygen consumption
Et al. – “and others” (Latin)
GE – General Electric
HPL – Human Performance Lab
HR – Heart Rate
ICD – Informed Consent Document
in - inches
kg – kilograms
$L \cdot min^{-1}$ - Liters per minute
LHTH - live high-train high
LHTL - live high-train low
LLTH - live low-train high
LLTL - live low-train low
m – meters
microL – microliters
ml – milliliters
$mL \cdot kg^{-1} \cdot min^{-1}$ – milliliters per kilogram per minute
mmhg – millimeters of mercury
$mmol \cdot L^{-1}$ – millimoles per liter
mph – miles per hour
n – number of subjects
NCAA -
PCS -
PT -
RCV - red blood cell volume
RER – respiratory exchange ratio
s or secs – seconds
SaO_2 – Saturation of oxygen
SD - Standard Deviation
SLR - Sea-level Resident

STS – Special Tactics Squadron
STTS - Special Tactics Training Squadron
TTE – time-to-exhaustion
U.S. – United States
USAF – United States Air Force
USAFA – United States Air Force Academy
VO_2max - Maximal Oxygen Uptake
VT – Ventilatory Threshold